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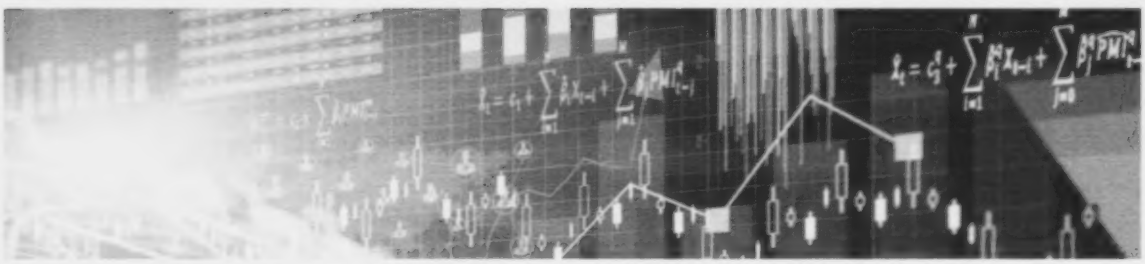

by Joel Wagner

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Downward Nominal Wage Rigidity in Canada: Evidence Against a "Greasing Effect"

by

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Abstract

The existence of downward nominal wage rigidity (DNWR) has often been used to justify a positive inflation target. It is traditionally assumed that positive inflation could "grease the wheels" of the labour market by putting downward pressure on real wages, easing labour market adjustments during a recession. A rise in the inflation target would attenuate the long-run level of unemployment and hasten economic recovery after an adverse shock. Following Daly and Hobijn (2014), we re-examine these issues in a model that accounts for precautionary motives in wage-setting behaviour. We confirm that DNWR generates a long-run negative relation between inflation and unemployment, in line with previous contributions to the literature. However, we also find that the increase in the number of people bound by DNWR following a negative demand shock rises with inflation, offsetting the beneficial effects of a higher inflation target. As an implication, contrary to previous contributions that neglected precautionary behaviour, the speed at which unemployment returns to pre-crisis levels during recessions is relatively unaffected by variations in the inflation target.

Bank topics: Inflation targets; Labour markets
JEL codes: E24; E52

Résumé

La rigidité à la baisse des salaires nominaux (RBSN) a souvent été invoquée pour justifier le ciblage d'un taux d'inflation positif. Il est communément admis qu'une inflation positive peut, en exerçant une pression à la baisse sur les salaires réels, « huiler les rouages » du marché du travail et faciliter les ajustements de ce marché durant les récessions. Le relèvement de la cible d'inflation aurait ainsi pour effet d'atténuer le chômage de long terme et d'accélérer la reprise économique après un choc défavorable. Dans le prolongement des travaux de Daly et Hobijn (2014), nous réexaminons ces questions à l'aide d'un modèle tenant compte des motifs de précaution qui influent sur les comportements de fixation des salaires. Nous confirmons que la RBSN engendre une relation de long terme négative entre l'inflation et l'emploi, ce qui concorde avec les résultats de contributions antérieures à la littérature sur le sujet. Nous constatons cependant que le nombre de travailleurs contraints par la RBSN à la suite d'un choc de demande négatif augmente avec l'inflation, ce qui compense les effets bénéfiques d'une cible d'inflation plus élevée. Il en découle, contrairement aux conclusions d'études antérieures qui passent sous silence les comportements dictés par la prudence, que les variations de la cible d'inflation ont relativement peu d'effet sur la vitesse à laquelle le taux de chômage retrouve ses niveaux d'avant-crise.

Sujets : Cibles d'inflation ; Marchés du travail
Codes JEL : E24, E52

Non-Technical Summary

Motivation and Question

Limitations in a worker's ability to adjust wages downward, known as downward nominal wage rigidity, have often been used to justify a positive inflation target. Most of the literature on DNWR has traditionally focused on the benefits of higher inflation by assessing its impact on the long-run level of employment. This paper studies whether higher inflation also accelerates economic recovery.

Methodology

Downward nominal wage rigidity (DNWR) is introduced into a standard business cycle model, which is solved non-linearly to capture households' precautionary behaviour. In this model, workers take into account the risks and potential costs associated with being unable to adjust wages downward when needed. As a result, they temper nominal wage increases, compared with a linearized model that ignores precautionary motives. Since the risk of being bound by DNWR in the future falls with a worker's current wage, the distribution of nominal wage growth is compressed to the left, with a disproportionately large fraction of workers close to the wage-freeze threshold. In this economy, we analyze the response of wages and unemployment to a large adverse demand shock and compute the speed of the recovery across a range of values for the inflation target.

Key Contributions

We show that the speed of the recovery is largely unaffected by the inflation target, contrary to previous findings. The result is due to precautionary behaviour. Higher inflation moderates the risk of being bound by DNWR, encouraging households to increase nominal wages, and this effect is stronger the lower the nominal wage growth. Since the number of workers close to the wage-freeze threshold increases with the inflation target, the incidence of DNWR at times of low aggregate demand is larger with a higher inflation target, counteracting any positive effect higher inflation has on the speed of the recovery. Finally, we show that this model can account for the joint dynamics of unemployment and wage growth in Canada during the Great Recession.

Future Research

During the Great Recession, wages continued to drop despite lower unemployment and only began to rise when unemployment approached its natural rate. This atypical relationship between wage growth and labour market slack is explained by our model in the case of severe recessions and it could affect the optimal timing of interest rate normalization. Optimal monetary policy in a model with DNWR and the zero lower bound of nominal interest rates is an interesting extension to explore in future research.

1 Introduction

Whether due to concepts of fairness, nominal illusion or historical conventions, downward nominal wage rigidity (DNWR) has often been used to justify a positive inflation target. As theorized by Phillips (1958), when labour demand is low and unemployment high, DNWR results in labour market corrections that occur disproportionately through the employment margin rather than through reduced wages. Economists such as Keynes (1936), Tobin (1972), Akerlof et al. (1996), Kim and Ruge-Murcia (2009) and Elsby (2009) have all argued that high inflation rates "grease the wheels" of the labour market by putting downward pressure on real wages while leaving nominal wages unchanged. A direct implication of this argument is that there exists a long-run trade off between unemployment and inflation that is worth being exploited.

At first glance, policymakers would be tempted to increase the inflation target in order to shorten the overall time required for unemployment to return back to pre-crisis levels. This conclusion would be supported by a model that abstracts from workers' heterogeneity and does not take into account the precautionary motives in wage-setting behaviour. Our research shows that this conventional logic breaks down in a model populated by risk-adverse workers who are heterogeneous in the marginal rate of substitution between consumption and leisure, and set their wage rate taking into account the risk of being bound by DNWR in the future. In particular, the speed at which unemployment returns to pre-crisis levels is largely unaffected by changes in the inflation target.

The absence of any positive effect of higher inflation on the speed at which labour markets correct is due to the precautionary behaviour of the worker. These precautionary motives change the optimal wage-setting behaviour relative to a standard representative agent model that neglects the impact of risk on the worker's wage-setting decision. In a model with heterogeneous risk-averse workers, a worker's nominal wage rate decision is based both on the worker's expectation of current and future inflation and on the risk associated with being bound by DNWR. For a given desired real wage, higher expected current and future inflation induces workers to be more aggressive in negotiating nominal wage increases. In addition, the risk of being bound by DNWR reduces the desired real wage as compared with the wage decision made by a risk-neutral worker. Across the distribution of nominal wage changes, the closer the worker is to the wage-freeze threshold, the higher the risk of being bound by DNWR in the future. As a result, the distribution is compressed to the left, where the wage restraint induced by risk aversion is the strongest.

Contrary to a model where workers do not exhibit any precautionary behaviour, the effect of inflation on nominal wages varies across the wage distribution. In particular, it is the strongest close to the wage-freeze threshold, where workers increase nominal wages as they attempt to defend their purchasing power and because they are less concerned about relying on nominal wage cuts to reduce real wages in the future. Since nominal wage pressures fall in nominal wage growth, the nominal wage growth distribution becomes more skewed to the left when the inflation target rises, increasing the fraction of workers close to the wage-freeze threshold. During an economic downturn, this implies a larger increase in the percentage of workers bound by DNWR, as all workers cut wages in response to lower labour demand. This rise in the number of workers bound by DNWR counteracts any positive effect higher inflation has on the speed at which unemployment recovers.[1]

Building on the work done by Daly and Hobijn (2014), this paper introduces DNWR into a New Keynesian model where forward-looking agents make optimal wage-setting decisions in response to both aggregate and idiosyncratic shocks and goods prices are perfectly flexible. Households supply a differentiated variety of labour types, each one subject to idiosyncratic shocks that vary the worker's willingness to provide their particular labour type. Each period, a fraction of workers are unable to adjust wages downward, with the remainder free to choose any non-negative wage rate.

This research differs from Daly and Hobijn (2014), who focus on explaining the non-linearities observed in wage growth and unemployment following a recession in the United States. Instead, using their research, this paper examines the effect of a worker's precautionary behaviour on the speed of economic recovery across inflation targets. This is done by comparing the half-life of unemployment across inflation targets after a negative demand shock. This approach is in contrast to Kim and Ruge-Murcia (2009) and Ehrlich and Motes (2016), who evaluate a "greasing effect" by the long-run disemployment effect of DNWR. Instead, this paper assesses the presence of a "greasing effect" in the labour market by directly comparing the speed at which unemployment returns to pre-crisis levels as the inflation target increases.

The remainder of the paper proceeds as follows: Section 2 explores the non-linear dynamics of unemployment and wages following the Great Recession in Canada. Section 3 then outlines the model used to replicate the sudden deceleration in wage growth experienced in Canada from 2008Q1 to 2012Q4. Section 4 discusses the calibration required to match

[1] If the inflation target is high enough such that the compression of wages at the wage freeze threshold disappears, then the greasing effect resulting from a higher inflation target re-emerges. However, the difficulty that comes with keeping inflation expectations anchored at these high levels makes their adoption unlikely.

what we observe in the Canadian data. Section 5 sketches and defends the conclusions listed above and section 6 concludes.

2 The Short-Run Phillips Curve in Canada

The focal point of this paper is the concept that DNWR altered the joint dynamics of labour and wage growth in Canada following the Great Recession. Figure 1 plots the transition path of wage growth and the unemployment gap observed in Canada and the United States during the Great Recession.[2] While the Canadian labour market experience differed substantially from that of the United States, the starkest of these differences is that the shock that led to the Great Recession did not lead to a dramatic drop in wages in Canada as it did for the United States. Rather, from the onset of the Great Recession up until unemployment reached its peak, there appears to be little downward pressure on wages. Only when unemployment peaked in 2009 did wages begin to decline. This flat trajectory is consistent with workers' inability to adjust wages downward. This causes unemployment to increase until a sufficient number of workers accept a wage freeze and aggregate wages start to decline. To fully appreciate the rationality behind the joint behaviour of unemployment and wage inflation observed in Canada, we first need to understand how the distribution of wage growth varied over the Great Recession.

As demonstrated by Card and Hyslop (1997), Brouillette et al. (2016) and Elsby (2009), with DNWR, the proportion of workers experiencing negative wage growth declines, with all these workers forced to accept a wage freeze instead of a wage cut. In addition, as pointed out by Elsby (2009) and Daly and Hobijn (2014), with DNWR, both workers and firms, aware of the risk of being bound by DNWR, reduce their nominal wage rate to avoid costly spells of underemployment when wages are disproportionately high. This precautionary behaviour results in the wage growth distribution also being compressed from the right. Therefore, the distribution of wage growth data should be asymmetric with a majority of wage changes being non-negative and a pronounced spike at zero. Brouillette et al. (2016) assess the importance of DNWR in Canada by evaluating the distribution of wage growth data collected from the Survey of Labour and Income Dynamics (SLID) from 1994 to 2011. This self-reporting survey follows individuals for 6 years, and collects information on, amongst other things, income

[2]Wage growth is calculated using principal component analysis (outlined in the Appendix), adjusted by the 10-year-ahead inflation forecast. This is done to isolate the impact of cyclical nominal wage growth from the impact anticipated inflation has on wage decisions. The unemployment gap is measured as the unemployment rate less the natural rate of unemployment. The natural rate of unemployment is interpreted here as the trend rate of unemployment. The methodology used to calculate the natural rate of unemployment is available in the Appendix.

and job status. Brouillette et al. (2016) focus on the portion of the labour force between 16 and 69 years old who were neither self-employed, unemployed nor unpaid workers. Looking at those surveyed who remained in their current job for 24 months, they calculate wage growth by assessing the hourly wage change from January to December. Figure 7 of their paper plots the distribution of average yearly wage growth observed from 2001 to 2008 and from 2009 to 2011. As shown, the proportion of the population bound by DNWR increased from 25% to 40%. The additional mass of workers at the wage freeze threshold appears to be the result of workers who had formally asked for a wage increase now accepting a wage freeze. Thus, Brouillette et al. (2016) conclude that DNWR is prevalent in Canada's labour market and that the number of people bound by DNWR increased during the Great Recession. Furthermore, their estimates for the number of workers experiencing wage freezes both before and during the Great Recession are substantially higher than Daly and Hobijn's (2014) estimates of 12% and 16% respectively for the United States. These results suggest that DNWR is more severe in Canada compared with the United States.

3 Model

The closed economy model used to replicate the non-linear transitional dynamics of unemployment and inflation experienced in Canada after the Great Recession is based on the discrete time model proposed by Daly and Hobijn (2014). Their work builds on the dynamic stochastic general equilibrium models of Benigno and Ricci (2011) and Fagan and Messina (2009), who were in turn inspired by the wage-setting model of Erceg, Henderson, and Levin (2000). The novel contribution of Daly and Hobijn's (2014) research is their focus on the non-linear transitional dynamics of unemployment and inflation following a negative demand shock. Their model is particularly adept at taking into account the evolution of the wage distribution following a negative demand shock. While the fraction of the workers who are unable to adjust wages downward is fixed, the fraction of workers where the restriction is binding varies over time. Thus, the number of workers bound by DNWR can rise and fall over the business cycle. To begin our discussion, let's first look at the behaviour of the firm.

3.1 The firm

A firm, operating within a perfectly competitive goods market, produces the aggregate good Y_t according to the following linear production function:

$$Y_t = A_t L_t. \tag{1}$$

Given technology A_t, production of the consumption good requires a labour input L_t. Technology grows at a stochastic rate $a_t = A_t/A_{t-1} - 1$. The aggregate labour bundle consists of a continuum of various labour types L_{it} provided by the household and is calculated as

$$L_t = \left[\int_0^1 L_{it}^{\frac{\eta-1}{\eta}} di\right]^{\frac{\eta}{\eta-1}}. \tag{2}$$

Differing labour types L_{it} are imperfect substitutes, earning varying wage rates, denoted by W_{it}. The labour demand elasticity, denoted by η, determines the degree to which one type of labour can be substituted for another.[3] The conditional input demand, and the nominal aggregate wage rate W_t are calculated as follows:

$$L_{it} = \left(\frac{W_t}{W_{it}}\right)^{\eta} L_t, \tag{3}$$

$$W_t = \left[\int_0^1 \left(\frac{1}{W_{it}}\right)^{\eta-1} di\right]^{-\frac{1}{\eta-1}}. \tag{4}$$

The aggregate price level is determined by the ratio of wages to technology $P_t = W_t/A_t$, implying a detrended real wage rate for labour type i of $w_{it} = \frac{W_{it}}{A_t P_t}$.

3.2 Household

The model consists of a single infinitely lived household with a continuum of members. The household chooses a path for consumption, wages and labour supply $\{C_t, w_{it}, L_{it}\}_{t=0,i=0}^{t=\infty,i=1}$ so as to maximize the present discounted value of lifetime utility

$$\sum_{t=0}^{\infty} \beta^t e^{-\sum_{s=0}^{t-1} D_s} \left[\ln C_t - \frac{\gamma}{\gamma+1}\int_0^1 Z_{it} L_{it}^{\frac{\gamma+1}{\gamma}} di\right], \tag{5}$$

where $\gamma > 0$ denotes the Frisch labour supply elasticity, β is the discount factor, D_s is a preference shock, and Z_{it} denotes the time-dependent idiosyncratic disutility experienced by households when providing labour type L_{it}. This idiosyncratic disutility is not constant, but rather varies over time. The disutility shock Z_{it} is drawn from a log normal distribution $F(Z)$ where $ln(Z)$ is $N\left(-\frac{\sigma^2}{2}, \sigma\right)$ with $E(Z) = 1$. Increases in Z_{it} increase the disutility incurred by the worker in providing labour type L_{it}, causing workers to demand a higher wage. It is assumed that each worker is too small to alter the aggregate wage rate, labour input, the price level or the interest rate, taking all four as given. Workers combine their wage rate

[3] We assume that each labour type can differentiate itself without cost.

decision and their labour supply decision into one decision over wages, taking firms' labour demand as given. They then maximize their lifetime utility subject to the following budget constraint:

$$B_t + P_t C_t = (1 + i_{t-1})B_{t-1} + \int_0^1 W_{it} L_{it} di. \tag{6}$$

The household provides $\int_0^1 L_{it} di$ units of labour to the firm, earning a total income of $\int_0^1 W_{it} L_{it} di$. The household possesses B_{t-1} nominal assets from the previous period, earning a nominal interest rate i_{t-1}. The household then chooses either to consume this income $P_t C_t$ or to increase its bond holdings B_t. Downward nominal wage rigidity is the final constraint binding the household's optimization problem. Each period, the household's members make a decision to either increase, decrease or keep the current wage rate W_{it} constant over time. A worker is unable to adjust wages downward with probability $\lambda \in [0, 1)$.

When wages are fully flexible (i.e. $\lambda = 0$), workers choose a wage rate that maximizes their lifetime utility (5), given the labour demand function (3) along with the aggregate real wage rate. The solution to the optimization problem faced by i^{th} member of the household can be written as follows.

$$w_{it}^f = \left(\frac{\eta}{\eta - 1}\right)^{\frac{\gamma}{1+\gamma}} Z_{it}^{\frac{\gamma}{1+\gamma}} L_{it}^{f\ \frac{\eta+\gamma}{1+\gamma}}, \tag{7}$$

implying an equilibrium labour supply of

$$L_t^f = \left(\frac{\eta}{\eta - 1}\right)^{\eta+\gamma} \left(\frac{1}{Z_t}\right)^{1+\gamma}, \tag{8}$$

where

$$Z_t = \left[\int_0^1 \left(\frac{1}{Z_{it}}\right)^{\frac{\gamma(\eta-1)}{\eta+\gamma}} dF(Z_{it})\right]^{-\frac{\eta+\gamma}{\gamma(\eta-1)}} = e^{\frac{\eta\sigma_z^2(1+\gamma)}{2(\gamma+\eta)}}. \tag{9}$$

The detrended steady-state level of output/employment under flexible wages L_t^f will serve as a measure of potential employment in our calculation of the unemployment rate.

When wages are fully flexible, agents choose an optimal wage based on the current state of the economy. With $\lambda > 0$, this is no longer the case. Even with no aggregate uncertainty, each individual of the household still faces uncertainty regarding the future value of the idiosyncratic shock Z_{it}. When $\lambda > 0$, the i^{th} member of the household takes into account the current value of Z_{it} and L_t, as well as the entire time-path for inflation π_t, technological growth, a_t, and preference shock, D_t, when determining the optimal wage decision for period t. The resulting optimization equation can be expressed through the following Bellman

equation:

$$V_t(w) = (1-\lambda)\int_0^\infty \max_{w_{it}\geq w}\left(\mathfrak{U}(Z_{it}, w_{it}, L_t) + \beta e^{-D_t}V_{t+1}(w')\right)dF(Z_{it})$$

$$+\lambda\int_0^\infty \max_{w_{it}\geq w}\left(\mathfrak{U}(Z_{it}, w_{it}, L_t) + \beta e^{-D_t}V_{t+1}(w')\right)dF(Z_{it}). \quad (10)$$

where $w' = w_{it}/((1+\pi_{t+1})(1+a_{t+1}))$. The optimal solution to the household's maximization problem will be a real wage rate w_{it} that takes into account the probability that they will be bound by DNWR. As a result, workers choose a real wage that is a fraction of those observed under flexible wages. The solution to equation (10) implies a steady-state value of employment L_t of

$$L_t = \left(\frac{\eta-1}{\eta}\right)^{\frac{\gamma}{1+\gamma}}\left(\frac{Z_t}{Z_t^*}\right)^{\frac{\gamma}{1+\gamma}}\left(\frac{1}{Z_t}\right)^{\frac{\gamma}{1+\gamma}}. \quad (11)$$

where the first component represents the distortionary effect of monopolistic competition in labour supply. The second component $\left(\frac{Z_t}{Z_t^*}\right)^{\frac{\gamma}{1+\gamma}}$ is the distortion to labour supply arising from DNWR. The aggregate disutility term Z_t^* is given by

$$\begin{aligned} Z_t^* = &\left((1-\lambda)\int_0^\infty\left(\frac{1}{Z}\right)^{\frac{\gamma(\eta-1)}{\eta(1+\gamma)}}\left(\frac{w_t^f(Z)}{w_t^*(Z)}\right)^{\eta-1}dF(Z)\right.\\ &+\lambda\int_0^\infty\left(\frac{1}{Z}\right)^{\frac{\gamma(\eta-1)}{\eta(1+\gamma)}}G_{t-1}^*(w_t^*(Z)(1+\pi_t)(1+a_t))\left(\frac{w_t^f(Z)}{w_t^*(Z)}\right)^{\eta-1}dF(Z)\\ &\left.+\lambda\int_0^\infty\left(\frac{1}{Z}\right)^{\frac{\gamma(\eta-1)}{\eta(1+\gamma)}}\left(\int_{w_t^*(Z)}^\infty g_{t-1}(w(1+\pi_t)(1+a_t))\left(\frac{w_t^f(Z)}{w_t^*(Z)}\right)^{\eta-1}dw\right)dF(Z)\right)^{-\frac{\eta(1+\gamma)}{\gamma(\eta-1)}}. \end{aligned} \quad (12)$$

where the optimal wage rate is $w_t^*(Z)$. The distribution of real wages $G_t(w)$ is calculated as

$$G_t(w) = (1-\lambda)F(Z_t(w)) + \lambda G_{t-1}(w(1+\pi_t)(1+a_t))F(Z_t(w)). \quad (13)$$

$g_t(\cdot)$ denote and density of the wage rates. The real wage distribution when wages are perfectly flexible (i.e. $\lambda = 0$) is simply $F(Z_t(w))$. Utilizing the steady-state level of employment under flexible wages, the unemployment rate with DNWR is calculated by the ratio

$(L_t^f - L_t)/L_t^f$. The natural rate of unemployment is then determined by the value of this ratio in the steady state. The unemployment gap is measured as the unemployment rate less the natural rate of unemployment.

The inclusion of DNWR implies that monetary policy can affect the real aggregate outcome of the economy. The central bank is assumed to follow a simple Taylor rule:

$$i_t = \frac{(1+\pi)(1+a)}{\beta}\left(\frac{y_t}{y}\right)^{\phi^Y}\left(\frac{1+\pi_t}{1+\pi}\right)^{1+\phi^\pi} - 1, \tag{14}$$

where π is the inflation target and a is the steady-state growth rate of technology. Lastly, ϕ^Y and $1+\phi^\pi$ denote the weight assigned by the central bank to the output/employment and inflation gaps respectively.

The solution to the model listed above will involve finding the optimal time path for $\{Y_t, L_t, i_t, \pi_t, r_t\}$ that satisfies the Euler equation, the production function (1), the monetary policy rule (14) as well as the Fisher equation $r_t = (1+i_t)/(1+\pi_{t+1}) - 1$. Finally, the detrended aggregate real wage rate w_t equals one in steady state.

4 Calibration

Table 1 outlines the parameter choices used to estimate the model. Starting with the household, the parameters governing the subjective discount factor β and the elasticity of labour supply γ are left unchanged from the values used by Daly and Hobijn (2014), with a value of 0.995 and 0.5 respectively. In order to match the joint behaviour of unemployment and wage growth observed in Canada during the Great Recession, the labour demand elasticity η is set equal to 2, which is lower than the 2.5 used by Daly and Hobijn for the United States. This reflects the fact that the degree of labour market regulations is higher in Canada than in the United States. As Benigno and Ricci (2011) illustrate, the rate at which workers lower their current wage (compared with optimal wage rate under flexible wages) increases as the substitutability across various labour types declines. Therefore the elasticity of labour demand will play an important role in matching the distinct transition path of both wages and unemployment as they return to steady state.[4,5] In addition, Loboguerrero and Panizza (2006) speculate that the macroeconomic consequences of DNWR are more severe

[4] The main conclusion, that a higher inflation target does not accelerate labour market corrections, is robust to the range of values for η.

[5] One should note that a majority of the parameter calibrations listed above impact the value of the natural rate of unemployment. As a consequence, the size of the idiosyncratic shocks will need to be calibrated to hold the steady-state level of unemployment constant at 7%.

for countries with heightened labour market regulations. Union participation rates, identified by Holden (2004) and Dickens et al. (2007) as a measure of labour market elasticity, is one feature that distinguishes the Canadian labour market from its American counterpart. The parameter choice for the elasticity of labour demand, η, is in the range of values used in the literature, ranging from 1.6 by Ratto et al. (2009) for the Euro area, to a value of 21 by Christiano, Eichenbaum and Evans (2005). Finally, the steady-state quarterly growth rate of labour augmenting technology a is set equal to 0.005, generating an annual growth rate of 2%.

The remaining parameters yet to be discussed are those that govern the policy decision of the monetary authority. The target inflation rate is set to 0.005 per quarter, implying a 2% annualized inflation target as adopted by the Bank of Canada. Daly and Hobijn (2014) calibrate the ϕ^Y and ϕ^π for the United States based on Rudebusch's (2009) calculations. To find the equivalent estimates for Canada, a regression is performed that relates the Bank of Canada's policy rate with inflation and the unemployment gap, following Rudebusch's (2009) approach. The policy rate is calculated as the quarterly average overnight money market financing rate and the inflation rate is calculated as the quarterly average percentage change in the core consumer price index, annualized. Lastly, the unemployment gap is measured by the difference between the unemployment rate less the natural rate of unemployment. The natural rate of unemployment, which is interpreted here as the trend unemployment rate, is calculated using the cointegrated approach adopted by Côté and Hostland (1996). The results of this regression imply that a 1% increase in inflation (above target), leads to a 2.767% increase in the Bank of Canada's policy rate, while a similar increase in the unemployment gap would elicit only a 1.2% increase in the policy rate. Information on the data series used in this approximation is available in the Appendix. Given these estimates, ϕ^Y and ϕ^π are set to 1.2 and 1.767 respectively.

5 Results

We are now in a position to understand the impact DNWR has on the joint dynamics of unemployment and inflation following an economic downturn in Canada. The focus of this section will be twofold. First, to what extent does DNWR impact the long-run Phillips curve (LRPC) in Canada? Second, is the speed of economic recovery improved when the inflation target is increased? To this end, we'll be looking at the transition paths of unemployment, inflation, interest rates, and the percentage increase in the number of workers bound by DNWR following a negative demand shock. This will be done across a range of inflation targets. We begin by assessing the degree of DNWR in the Canadian labour market.

5.1 Transition Path Back to Pre-Crisis Levels

In this section we examine whether the same mechanism that explains the curvature in the short-run Phillips Curve (SRPC) for the United States can also explain the non-linear transition path of unemployment and inflation observed in Canada following the Great Recession. Since calculations for output and inflation are dependent on the distribution of wage growth in the previous period, the model outlined in Section 3 cannot be solved analytically and must be solved numerically. A detailed step-by-step outline of how this numerical exercise is performed is available in the Appendix. The transition path of unemployment and wage inflation implied by our model is determined by the intersection of aggregate demand and the short-run aggregate supply (SRAS) as they respond to a negative demand shock given by the following law of motion:

$$D_t = \rho_D D_{t-1} + \epsilon_t, \tag{15}$$

where ρ_D determines the persistence of the preference shock and ϵ_t is an innovation shock to preferences. As done by Daly and Hobijn (2014), the persistence of the preference shock is set equal to 0.95. The preference innovation ϵ_1 is set to match the initial increase in unemployment gap observed in Canada during the Great Recession.

Figure 2a plots the joint dynamics of unemployment and inflation in response to a negative demand shock across various degrees of DNWR. For each value of λ, the variance of idiosyncratic shock is adjusted in order to keep the natural rate of unemployment constant across simulations. For comparison, Figure 2 also includes the transition path of unemployment and wage inflation observed in Canada following the Great Recession. As can be seen in Figure 2b, both a high degree of DNWR (higher value of λ) along with a lower degree of labour demand elasticity (lower value of η) are required to replicate the initial flat trajectory, as well as the pent-up wage deflation observed in Canada during the Great Recession. Decreasing the elasticity of labour demand decreases the responsiveness of wage inflation in response to the negative demand shock. The degree of DNWR determines the extent to which SRAS curve shifts out, with higher values leading to a stronger response in unemployment, and a lessened response in inflation. This explains both the relatively flat initial trajectory as well as the deep decline in wages. Given the parameter choices listed in Table 1, the lower bound for the percentage of the working population subject to DNWR is approximately 90% 95%. These values are those necessary, given our parameter choices, to replicate the relatively small decline in wage inflation in response to a negative demand shock during the first few periods. For the remainder of the analysis, 95% will be used as

our benchmark calibration for λ. With $100(1-\lambda^4)\%$ of workers able to reduce wages annually, this value for λ is also able to reproduce Brouillette et al.'s (2016) observation that approximately 20% of workers experienced a wage cut using SLID data from 1994 to 2011.

As demonstrated in Figure 2c, the size of the demand shock also has a role in determining joint dynamics of unemployment and inflation in response to a negative demand shock. As one would expect, larger disruptions to the economy lead to a greater decline in wage growth as agents become increasingly willing to reduce wages as unemployment increases. This is in line with Benigno and Ricci (2011) who show that the workers become more flexible in their wage-setting behaviour when the expected increase in unemployment is large.

5.2 Long-Run Phillips Curve

The LRPC is largely in line with the conventional wisdom on the "greasing effect" in the long run. Higher inflation targets reduce the natural rate of unemployment. Figure 3 plots the LRPC for $\lambda = \{0.4, 0.6, 0.8, 0.90, 0.95\}$ with the variance of the idiosyncratic shock held constant. As can be seen in Figure 3, the long-run Phillips curves are not vertical, but rather become flatter for a progressively lower inflation target.

Adopting the language of Benigno and Ricci (2011), a worker's desired wage rate is defined as the optimal wage rate that a worker would choose if the worker was free to choose any non-negative wage rate in the current period. Due to the precautionary behaviour of the household, in a low-inflation environment, workers lower their current desired wage rate to avoid the possibility of being bound by DNWR in the future. When bound by DNWR, the worker's actual wage is limited to a value greater than or equal to the worker's desired wage rate, leading to a decline in employment. With DNWR binding for more workers when long-run inflation is low, this leads to a decline in employment and a bending of the LRPC. When the inflation target is near zero, a marginal increase in the long-run inflation rate leads to larger increase in employment when compared with the same marginal increase at a higher inflation target. The rate at which long-run unemployment declines in response to a progressively higher inflation target increases as the degree of DNWR increases. For example, when the inflation target increases from 2% to 3%, the natural rate of unemployment declines by 0.23% when $\lambda = 0.60$, compared with 0.74% when $\lambda = 0.95$. Likewise, for the same increase in the inflation target, output increases by 0.12% when $\lambda = 0.60$, to 0.76% when $\lambda = 0.95$.

These results validate the findings by Kim and Ruge-Murcia (2009), who solve for the optimal monetary policy with asymmetric wage adjustment cost. The solution to their

Ramsey problem suggests an optimal grease inflation of 0.35% per annum, increasing to 0.75 when a strict inflation target is adopted. This would be in line with the disemployment effect of low inflation, and the interpretation of "greasing the wheels" as argued by Elsby (2009). The bending of the LRPC found here also validates the results found by Ehrlich and Montes (2016). In their paper, they study the empirical relationship between DNWR and employment outcomes among establishments in western Germany. In their research, they find that DNWR prevents on average roughly a quarter of all wage cuts, leading to a 0.7% increase in the layoff rate. They also find that this value rises with the severity of DNWR. Qualitatively, these are the same results found in Figure 3, with the natural rate of unemployment increasing with the severity of DNWR.

5.3 The Inflation Target and the Speed of Recoveries

After explaining the role of DNWR in generating a LRPC, we now focus on its impact on macroeconomic adjustment after a negative demand shock. We show that increasing the inflation target does not accelerate the speed at which unemployment returns to its natural rate following a recession. This turns out to be due to the risk-compensating behaviour of the worker, which results in the cyclical component of DNWR becoming increasingly volatile with a higher inflation target.

In order to understand the impact a higher inflation target has on the speed at which labour markets recover, Figure 4 plots the impulse response functions (IRF) of the nominal interest rate, the inflation rate, the percentage increase in the number of workers bound by DNWR and the unemployment gap to a negative demand shock across various inflation targets. As can be seen in Figure 4, the similarity in the response of unemployment across inflation targets is striking. There appears to be little evidence that a higher inflation target eases labour market corrections. Instead, the speed at which unemployment recovers following a negative demand shock remains relatively unchanged across the inflation target, a result that appears to be due to the risk compensating behaviour of workers when determining their desired real wage. As can be seen in Table 2, the half-life of unemployment is the same across inflation targets at approximately 4 quarters.

Figure 5a plots the distribution of nominal wage growth when workers exhibit precautionary behaviour when setting wages. For comparison, Figure 5b plots the naïve distribution that would exist if workers did not exhibit any precautionary behaviour. The naïve distribution is produced by calculating the flexible nominal wage growth distribution, with a fraction λ of workers who were planning to have wages cut forced to instead accept a wage freeze.

With a real wage distribution $G_t(w) = F(z_t(w))$, this change effectively raises workers' real wages up to their flexible wages rate levels, offsetting precautionary behaviour. This produces the naïve distribution, shown in Figure 5b when $\pi = 2\%$. As can be seen in Figure 5a, the precautionary behaviour of the worker implies that the wage growth distribution is compressed from the right. This is due to the fact that the risk of being bound by DNWR increases monotonically with a worker's wage rate. As a result, the percentage of workers negotiating only a small wage increase rises when compared with an analogous model without precautionary behaviour. With the nominal wage growth distribution compressed from the right, the percentage of workers at the wage freeze threshold includes not only those who would have preferred a wage cut but also those who would have negotiated a modest wage increase if not for this precautionary behaviour.

When the inflation target increases, the risk of being bound by DNWR declines, causing these workers to respond by negotiating wages upwards. As can be seen in Figure 5a, an increase in the inflation target from 2% to 4% results in a decline in the percentage of workers bound by DNWR, with many of these workers negotiating only a modest wage increase instead. In a DNWR model without precaution, workers respond to an increase in inflation by shifting wage expectations upwards, keeping real wages constant. This would lead to a drop in the percentage of workers bound by DNWR (as observed in the model with precautionary behaviour) as well as a slight decline in the number of workers with a wage increase near the wage freeze threshold. This is demonstrated by the naïve distribution, shown in Figure 5b. Comparing Figure 5a with precaution to Figure 5b without, the percentage of workers negotiating a wage increase rises with the inflation target, with the percentage of workers earning only a modest wage increase rising rather than falling when workers exhibit precautionary behaviour.

Wages rise in response to the increase in the inflation target due to both the reduced risk associated with being bound by DNWR, referred to as the "precautionary effect," and the "mechanical effect" resulting from workers increasing nominal wages to preserve purchasing power. Figure 6 separates the "precautionary effect" from the "mechanical effect" on wage growth resulting from an increase in the inflation target. Since the "precautionary effect" causes real wages to rise when the risk of DNWR declines, then the proportion of wage increases due to precaution can be calcuated by the increase in real wages. As can be seen in Figure 6, the precautionary effect is strongest close to the wage freeze threshold, where the increase in the number of workers earning a modest wage increase rises primarily by the reduction in precautionary behaviour. As wage growth rises, the precautionary motive declines, and the majority of wage increases appears to be motivated by preserving purchasing

power. Thus it appears that the increase in the number of workers near the wage freeze threshold when the inflation target rises is due primarily to the precautionary effect rather than the mechanical effect that comes with higher inflation.

During an economic downturn, the rise in number of workers earning a modest wage implies a larger increase in the percentage of workers bound by DNWR as all workers cut their wage growth expectations. While a higher inflation target reduces the risk of being bound by DNWR, the number of workers who find this restriction binding during a recession increases with a higher inflation target. As demonstrated in Figure 4, this results in the cyclical component of DNWR increasing for a progressively higher inflation target. Therefore, the positive "greasing effect" of higher inflation through reduced unemployment is offset by the increase in unemployment as more workers are bound by DNWR.

Proponents of the positive "greasing" effects of a higher inflation target argue that higher targets allow workers bound by DNWR to reduce their real wage while leaving nominal wages unchanged. While there is a long-run disemployment effect of DNWR when inflation targets are low, the claim that a higher inflation target eases economic recovery in the short run is largely exaggerated. The critical assumption made by previous research is that a rational worker does not adjust his or her desired real wage rate in response to changes in the risk of DNWR. When the precautionary behaviour of the worker is taken into account, the "greasing" effect of a higher inflation target is counteracted by an increase in the percentage of workers bound by DNWR. As a consequence, the transition path of unemployment across inflation targets is virtually identical.

There are exceptions to the conclusions listed above. This paper abstracts from a variety of other frictions such as sticky prices as well as rigidities preventing real wages from adjusting upwards. The latter would likely induce further compression of the wage distribution. The impact of these frictions on macroeconomic adjustment is left to future research.

As a counterfactual, Figure 7 reproduces the same IRFs listed in Figure 4 when workers no longer exhibit any precautionary behaviour when setting their real wages. This is done by adopting the naïve nominal wage growth distribution rather than the precautionary distribution. The transition path for the interest rate, inflation, unemployment, and the percentage increase in the number of workers at the wage freeze threshold is calculated for the range of inflation rate targets $\pi = \{1\%, 2\%, 3\%, 4\%\}$.[6] As can be seen in Figure 7, when the time path for the wage growth distribution no longer reflects precautionary behaviour, the

[6]Details on the methodology used for this experiment are available in the Appendix.

original hypothesis re-emerges, with higher inflation targets accelerating the speed at which unemployment returns to pre-crisis levels.

A robustness check is performed to assess whether any of the main conclusions listed above are affected by the size of the demand shock. The results of this experiment are shown in Figure 8, where the size of the negative demand shock is increased by a factor of two. In addition, information on the half-lives of unemployment for each inflation target is listed in Table 2. As can be seen in Figure 8, a higher inflation target does appear to elicit a mild greasing effect, with unemployment returning to pre-crisis levels at a faster rate when the inflation target rises. As can be seen in Table 2, increasing the inflation target from 2% to 3% appears to reduce the half-life of unemployment from six quarters to five. This, however, has more to do with the monetary authorities' position on stabilizing inflation than on a "greasing effect" in the labour market. As seen in Figure 8, with DNWR, a higher inflation target leads to a greater decline in inflation. In addition, due to the non-linear behaviour of unemployment and wage growth, inflation continues to decline even as unemployment begins to recover. With a high weight on the inflation gap (higher than Rudebusch's (2009) estimate of 1.3 for the United States), the continuing decline in inflation encourages the monetary authority to continue reducing the policy rate further. This helps bolster unemployment, resulting in a faster recovery in unemployment as the inflation target rises. Therefore, a monetary authority that is highly committed to inflation stabilization will experience a "greasing effect" due to the increased volatility of inflation rates that accompanies a higher inflation target. This is hardly the "greasing effect" theorized by Phillips (1958). Rather, as can be seen in Figure 9, when the weight on the inflation gap is reduced by half, the original hypothesis re-emerges, with unemployment returning to pre-crisis levels at roughly the same speed across inflation targets. Thus, it appears that increasing the inflation target does not expedite the speed an economy recovers during an economic downturn. Rather, it is the central bank's commitment to stabilizing inflation that can accelerate the return of unemployment back to pre-crisis levels.

6 Conclusion

Tobin (1972) theorized that a positive inflation target could "grease the wheels" of the labour market, and therefore be used to partially offset the negative effect of DNWR by allowing for greater flexibility in real wages. When dissecting this claim, this paper finds that a higher inflation target leads to the positive effect of lower unemployment in the long run; however, the speed at which unemployment returns to pre-crisis levels in the short run remains unaffected across inflation targets. Rather, a higher inflation target causes workers

with perfect foresight to choose a more aggressive real wage rate. While a higher inflation target reduces the number of people bound by DNWR, the percentage increase in the number of workers who find this restriction binding during a recession rises with the inflation target. Thus the "greasing" effect derived from a higher inflation target is almost entirely eroded by the household's wage response. There does, however, exist a trade-off between output and inflation in the long run, with a higher inflation target leading to a lower natural rate of employment. In light of these results, the benefit of raising the inflation target to address DNWR has been likely overstated.

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7 Appendix

7.1 Model Solution

Since the steady-state distribution of wage growth and hence the household's value function cannot be solved analytically, the following numerical exercise is performed: Starting with the steady-state value of labour, the household value function and the wage growth distribution under flexible wages, we first iterate over the Bellman equation until the value function converges.[7] This allows us to calculate the wage-setting schedule $w(Z)$ for the entire possible range of values of Z. Since the household's wage-setting decision and hence the distribution of real wages $G(w)$ relies on the distribution of wages in the previous period, the steady-state distribution of real wage growth can be solved by iteration over this recursive equation until the two distributions converge. With both the wage-setting schedule and the distribution of real wages, the value for labour L can be updated. Using these values for L and $G(w)$, we iterate over both the Bellman equation, and then the wage growth distribution again until the value of labour L has converged.

The transition path for unemployment and inflation is calculated through the evolving interaction of aggregate demand (AD) and the short-run aggregate supply (SRAS) curves in response to either of the two shocks considered. The AD curve is calculated by a combination of both the Taylor rule (14) and the Euler equation for the consumption savings decision of the household and shifts in response to either variation in preferences or shifts in technology. The SRAS curve calculates the relationship between unemployment and inflation resulting from workers optimizing over their lifetime utility subject to the possibility of being bound by DNWR, as outlined in equation (10). Since this paper's focus is on the response of unemployment and wage growth following a negative demand shock, the solution for the time path for these variables will focus on this shock. Solving for the transitional dynamics of this model after a technology shock are analogous.

Starting in period T and assuming that the entire economy (excluding the demand shock) is in steady state over the entire time path $t = 1...T$, the output path $\{y_t\}_{t=1}^{T}$ is calculated by either iterating up or down the inflation rate until the implied output given by both the AD and SRAS curve are equal. This implies an inflation rate $\{\pi_t\}_{t=1}^{T}$, which can be used to

[7] Estimates for the value function $V_t(w)$, the wage-setting schedule $w_t(Z)$ as well as the distribution of real wage growth $G_t(w)$ are calculated using polynomial approximations. Each of these is based on the distribution $F(Z)$, which has been truncated such that with an upper bound $\overline{Z}$ and lower bound $\underline{Z}$ imply $1 - F(\overline{Z}) = F(\underline{Z}) = 0.005$. This, together with the fact that $\pi \geq 0$ implies that the real wage distribution $G_t(w)$ is bounded along the entire time path.

calculate the wage schedule $\{w_t(Z)\}_{t=1}^{T}$. Using forward iteration, $\{w_t(Z)\}_{t=1}^{T}$ can be used to calculate the time path of the distribution of real wages $\{G_t(w)\}_{t=1}^{T}$. These two steps are then repeated until the time path for the labour converges.

7.2 Counterfactual Exercise

As above, the transition path for unemployment, inflation, output, the interest rate and the distribution of wage growth is solved through a two-stage iteration process. The second of these two iteration processes determines the transition path of wage-growth distribution over time. The counterfactual exercise performed in Section 5.3 is done by performing these two iteration processes simultaneously; one where workers exhibit precautionary behaviour, and the real wage growth is given by equation (13), and one where workers do not exhibit any precautionary behaviour. The second scenario involves replacing the precautionary real wage growth distribution, shown in equation (13) with the equivalent naïve distribution. The naïve real wage growth distribution is calculated by adding $\lambda F(Z(w)) - \lambda G(w(1+\pi)(1+a))F(Z(w))$ to the real wage distribution $G(w)$ shown in equation (13), where $G(w(1+\pi)(1+a))$ is the steady state distribution of wages when workers exhibit precautionary behaviour, calculated in the first iteration. This effectively raises real wages to their flexible wage rate levels. Lastly, the size of the negative demand shock was increased to 0.03 to approximate the increase in unemployment, as done in the benchmark model. This exercise is then repeated for $\pi = \{1\%, 2\%, 3\%, 4\%\}$.

7.3 Wage Data

The annualized wage-growth rate for Canada from 1998Q3 to 2014Q3 is calculated using principal component analysis. The four measures of wage growth used in this analysis include average hourly wage rates, average weekly wage rates, the median hourly wage rate and the median weekly wage rate. Each of these was obtained from Statistics Canada, Survey of Labour Income and Dynamics, where we calculate the average growth rate of each seasonally adjusted quarterly time series from one year prior. A majority of the time series follow a similar pattern with the exception of the annualized growth rate of average hourly wage rates, which dropped substantially during the periods following the recession. Thus, the principal component analysis provides a more robust measure of wage growth over the time horizon considered.

7.4 Taylor Rule Approximation Data

Estimates for the two Taylor parameters are estimated using the following data: the quarterly interest rate is calculated using the quarterly average of the overnight money market financing rate. The inflation rate is calculated using the core inflation rate series (v108785713). Lastly, the unemployment gap is measured as the difference between the quarterly unemployment rate of those between 15 and 64 years of age (from the CANSIM Table 282-0087) less the natural rate of unemployment calculated using the cointegrated approach adopted by Côté and Hostland (1996). In their paper, they utilize information on unemployment and other labour market variables including payroll taxes and an employment insurance index (see Sargent (1995)). The natural rate of unemployment is then calculated as the fitted value from a single-equation cointegrated analysis of the relationship between unemployment and the remaining variables.[8]

[8] A special thanks to Mikael Khan for providing this data series on the natural rate of unemployment in Canada.

Table 1
Parameter Values

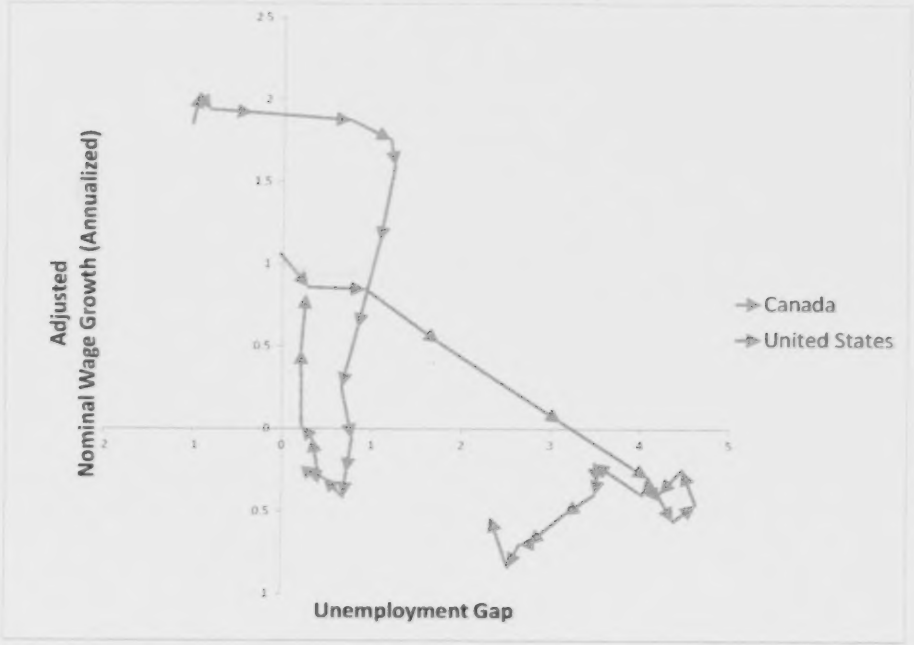
Parameters	Function	Parameter Value
η	Labour demand elasticity	2
γ	Frisch elasticity of labour supply	0.5
β	Discount factor	0.995
π	Target inflation	0.005
a	Technology growth	0.005
σ	Standard deviation of the idiosyncratic disutility shock to labour	0.266
Historical Taylor Rule Estimates for Canada 1990Q1-2015Q4		
ϕ^Y	Taylor rule parameter for the output gap	1.201 (4.366)
$1+\phi^\pi$	Taylor rule parameter for the inflation gap	2.767 (6.993)

The above estimates for ϕ^Y and ϕ^π are calculated by regressing the inflation rate and the unemployment gap on the overnight money market financing rate. The R^2 statistic is 0.40, t-statistics are in parentheses.

Table 2
Half-Life of Unemployment

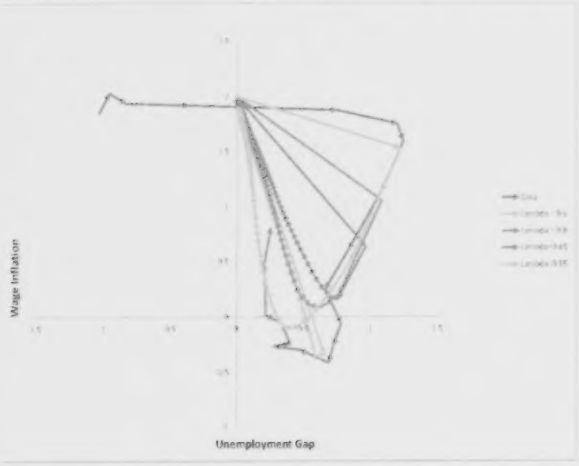
	Peak Unemployment	3/4	1/2	1/4
Benchmark				
$\pi = 1\%$	1.25	Q2	Q1	Q10
$\pi = 2\%$	1.22	Q2	Q1	Q9
$\pi = 3\%$	1.19	Q2	Q1	Q11
$\pi = 4\%$	1.14	Q2	Q1	Q16
Varying Degrees of DNWR				
$\lambda = 0.4\%$	0.43	Q6	Q13	Q26
$\lambda = 0.6\%$	0.69	Q1	Q12	Q25
$\lambda = 0.80\%$	0.98	Q2	Q8	Q21
$\lambda = 0.95\%$	1.22	Q2	Q1	Q9
Counterfactual Experiment				
$\pi = 1\%$	1.26	Q6	Q9	Q16
$\pi = 2\%$	1.23	Q4	Q7	Q15
$\pi = 3\%$	1.22	Q3	Q6	Q16
$\pi = 4\%$	1.186	Q3	Q6	Q19
Increased Negative Demand Shock				
$\pi = 1\%$	2.40	Q1	Q9	Q16
$\pi = 2\%$	2.36	Q3	Q6	Q12
$\pi = 3\%$	2.39	Q2	Q5	Q10
$\pi = 4\%$	2.33	Q2	Q1	Q11

Figure 1
Short-Run Wage Phillips Curves
Canada and the United States
2008Q1 to 2012Q4

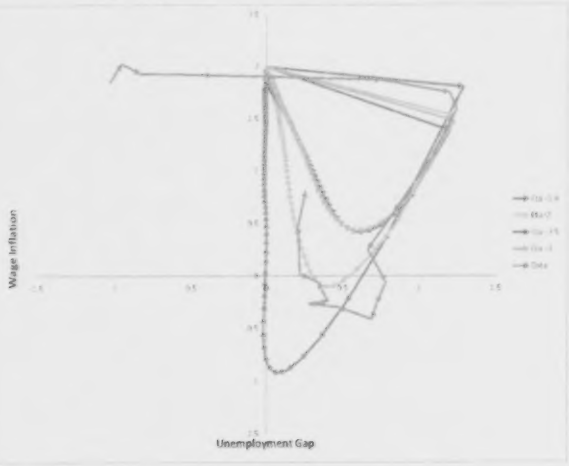


The adjusted nominal wage growth is calculated using principal component analysis to calculate the annual wage growth, less the 10-year-ahead forecast expectations. Further details are available in the Appendix. Calculations for the United States comes from Daly and Hobijn (2014).

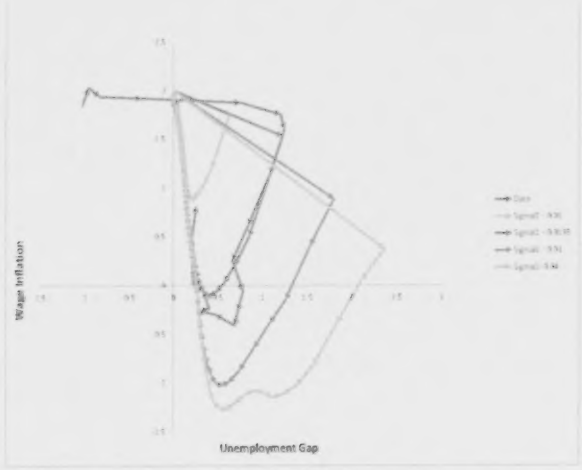
Figure 2
Short-Run Phillips Curves
in Response to a Negative Demand Shock
Holding the Natural Rate of Unemployment Constant



(a) Variation in DNWR



(b) Variation in Labour Demand Elasticity



(c) Variation in Size of the Demand Shock

For each value for λ and η, the volatility of the idiosyncratic shock is adjusted to keep the natural rate of unemployment fixed at 7%. The natural rate of unemployment is then removed from each of the short-run Phillips curves plotted. This is then overlapped with the Canadian wage Phillips curve shown in Figure 1.

Figure 3
Long-Run Phillips Curve
Varying the Degree of DNWR λ

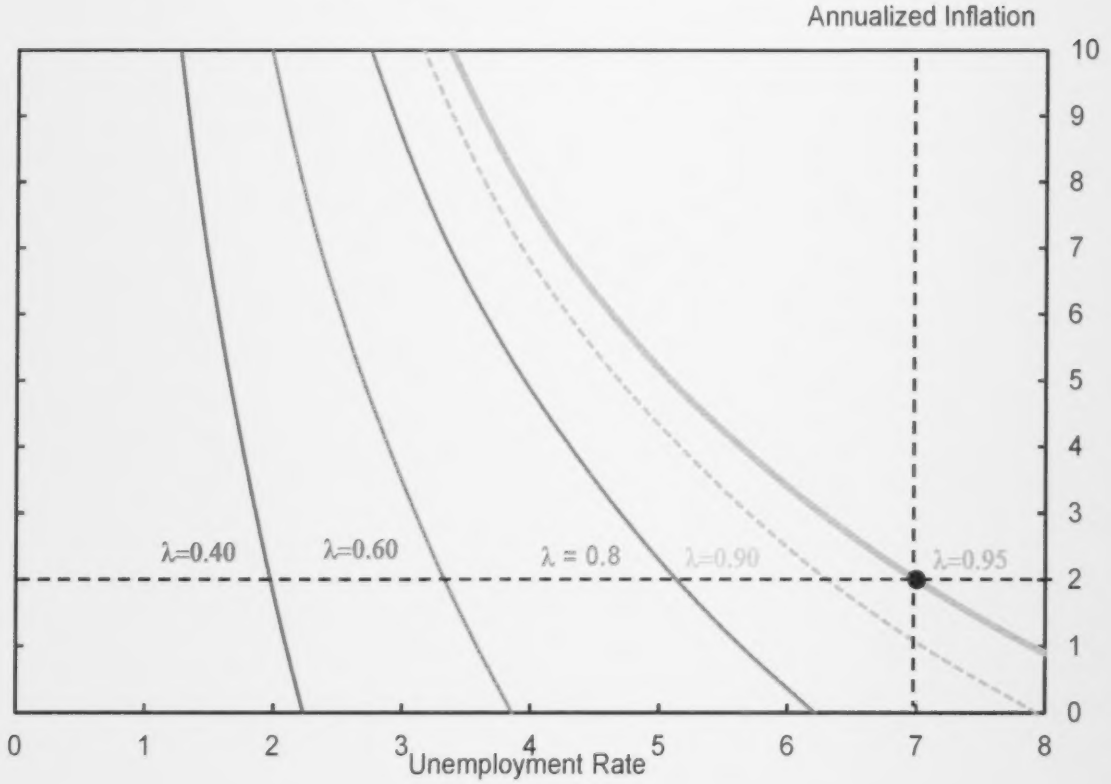
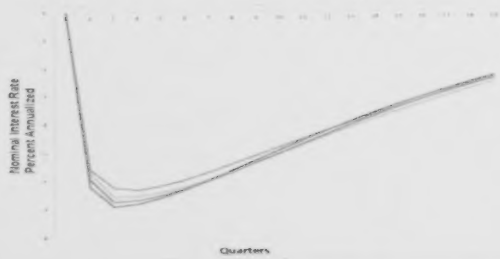
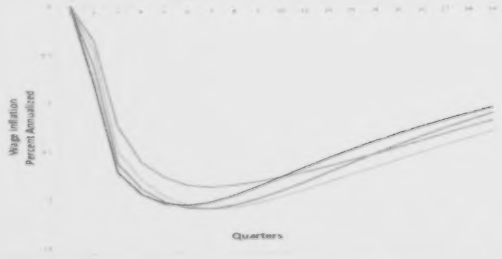


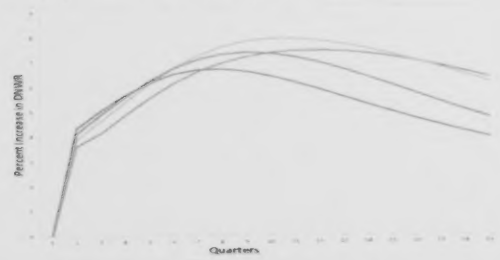
Figure 4
Impulse Response Functions
Negative Demand Shock:
$\bar{\pi} = \{1\%,\ 2\%,\ 3\%,\ 4\%\}$



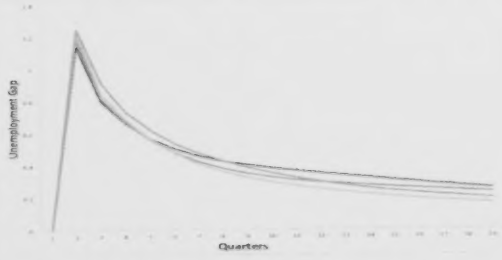
(a) Interest Rates (Annualized)



(b) Inflation Rates (Annualized)



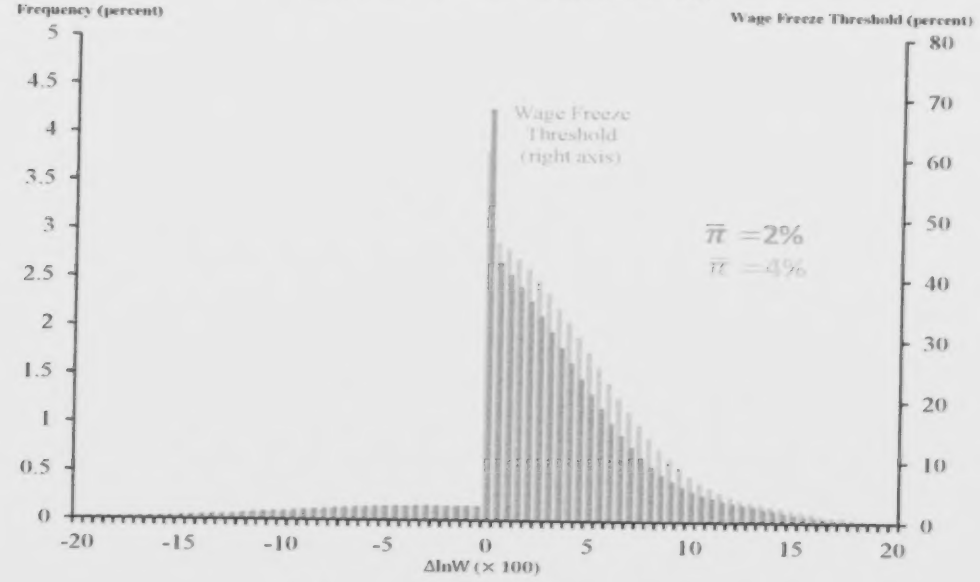
(c) Percentage of Workers with Zero Wage Growth



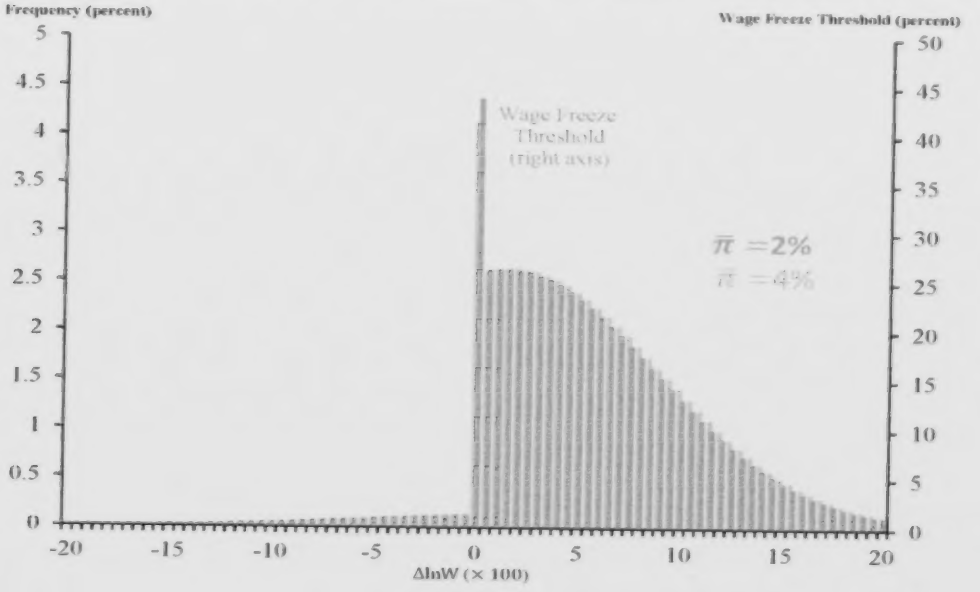
(d) Unemployment Gap

For the first four panels $\pi = \{1\%,\ 2\%,\ 3\%,\ 4\%\}$ is plotted as {blue, green, red and purple} respectively. Each variable is plotted as its deviation from steady state to highlight the cyclical component.

Figure 5
Density of Quarterly Log Wage Changes in Steady-State
$\bar{\pi}$ Increases from 2% to 4%



(a) Wage Distribution With Precautionary Behaviour

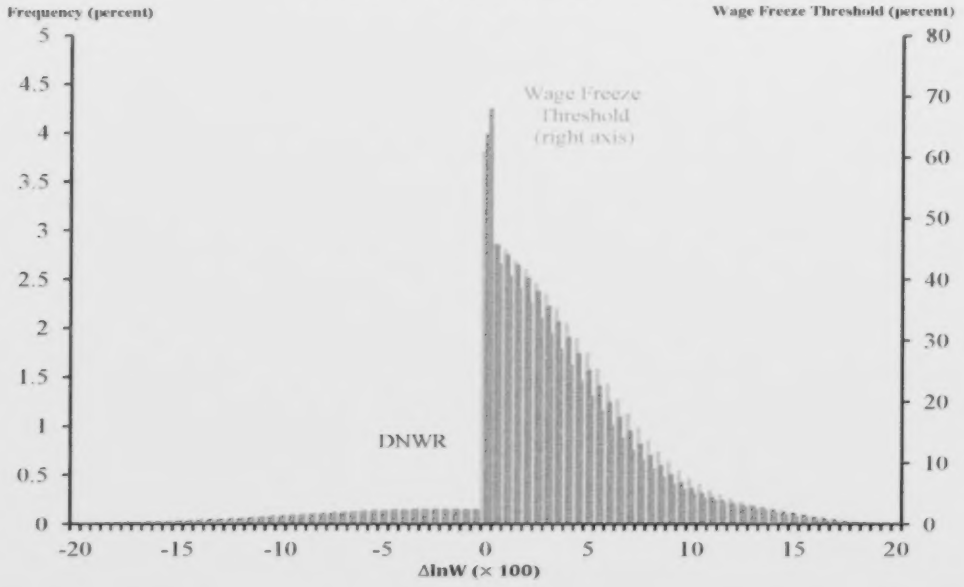


(b) Naïve Wage Distribution

The wage growth distribution when the inflation target $\bar{\pi} = 2\%$ is shown in blue. The wage growth distribution when $\bar{\pi} = 4\%$ is shown in green. The naïve distribution is calculated assuming no DNWR, with $(1 - \lambda)$ of wage cuts swept up to the wage freeze threshold.

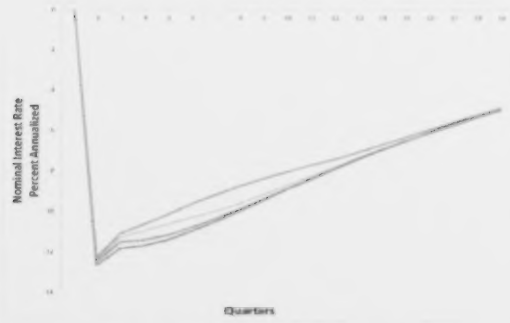
Figure 6

Mechanical versus Precautionary
Density of Quarterly Log Wage Changes in Steady-State
$\bar{\pi}$ Increases from 2% to 4%

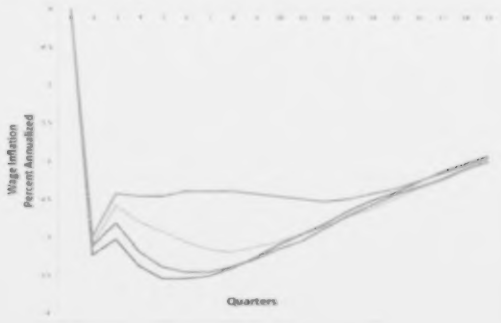


The wage growth distribution when the inflation target $\pi = 2\%$ is shown in blue. The wage growth distribution when $\bar{\pi} = 4\%$ is shown in green. The distribution shown in red is the portion of wage increases across the distribution due to the precautionary behaviour of the worker. The remaining increase in wages (the difference between the red to green distributions) is due to the mechanical effect of inflation on nominal wages.

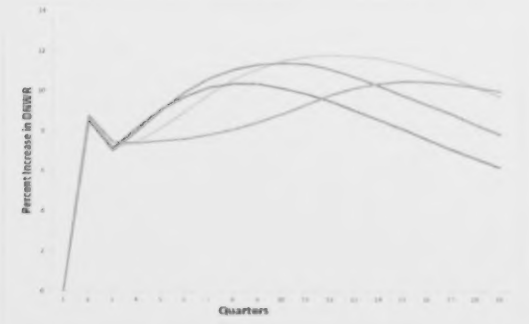
Figure 7
Impulse Response Functions
Negative Demand Shock:
Naïve Distribution
$\bar{\pi} = \{1\%,\ 2\%,\ 3\%,\ 4\%\}$



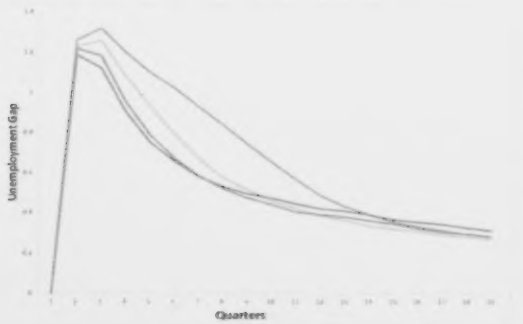
(a) Interest Rates (Annualized)



(b) Inflation Rates (Annualized)



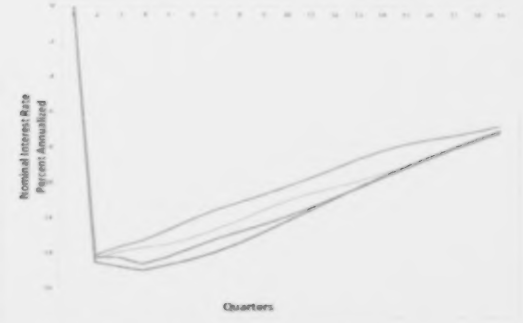
(c) Percentage of Workers with Zero Wage Growth



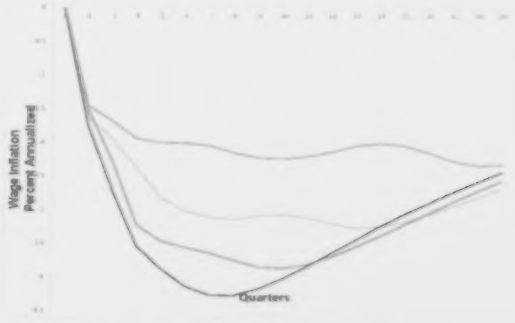
(d) Unemployment Gap

In each panel $\pi = \{1\%,\ 2\%,\ 3\%,\ 4\%\}$ is plotted as {blue, green, red and purple} respectively. Each variable is plotted as its deviation from steady state to highlight the cyclical component, where the naïve distribution, described in section 5.3 is used rather than the precautionary distribution.

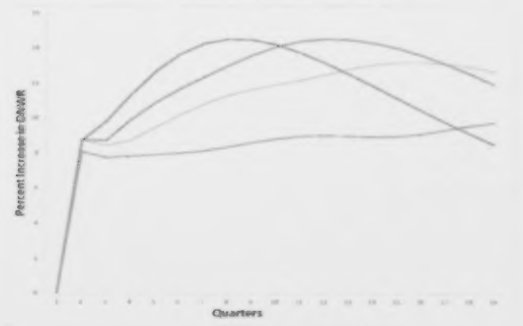
Figure 8
Impulse Response Functions
Large Negative Demand Shock:
$\bar{\pi} = \{1\%,\ 2\%,\ 3\%,\ 4\%\}$



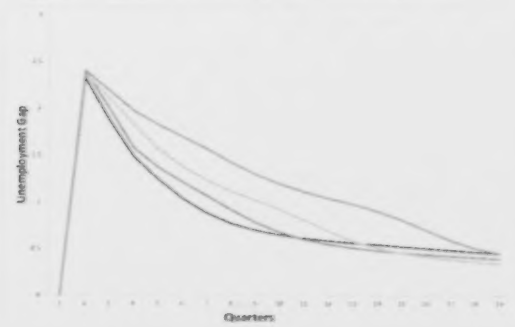
(a) Interest Rates (Annualized)



(b) Inflation Rates (Annualized)



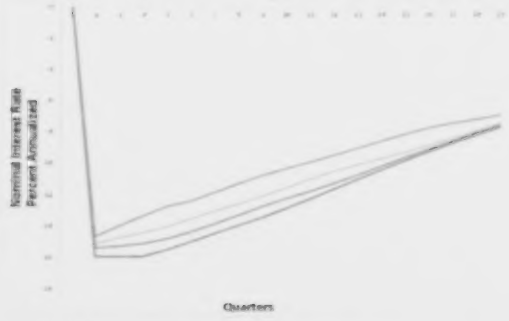
(c) Percentage of Workers with Zero Wage Growth



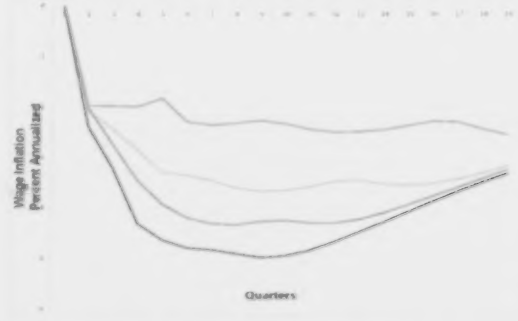
(d) Unemployment Gap

In each panel $\pi = \{1\%,\ 2\%,\ 3\%,\ 4\%\}$ is plotted as {blue, green, red and purple} respectively. Each variable is plotted as its deviation from steady state to highlight the cyclical component. Each figure demonstrates the IRFs under the benchmark calibration when the size of the negative demand shock is increased by a factor of two.

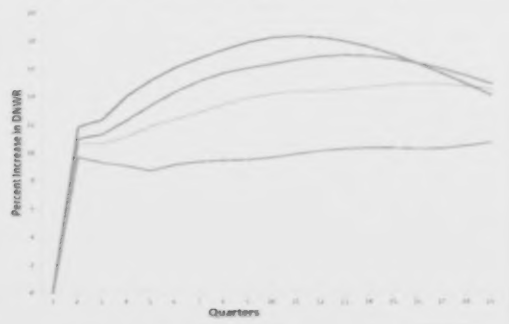
Figure 9
Impulse Response Functions
Large Negative Demand Shock:
Lower ϕ^{π}, $\bar{\pi} = \{1\%,\ 2\%,\ 3\%,\ 4\%\}$



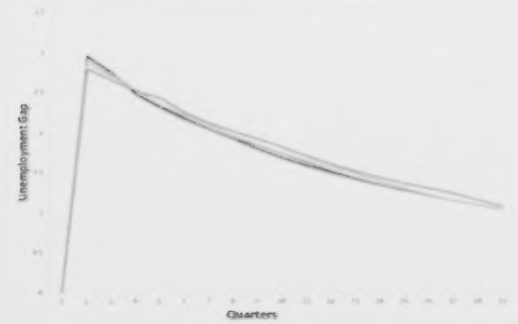
(a) Interest Rates (Annualized)



(b) Inflation Rates (Annualized)



(c) Percentage of Workers with Zero Wage Growth



(d) Unemployment Gap

In each panel $\pi = \{1\%, 2\%, 3\%, 4\%\}$ is plotted as {blue, green, red and purple} respectively. Each variable is plotted as its deviation from steady state to highlight the cyclical component. Each figure demonstrates the IRFs under the benchmark calibration when the size of the negative demand shock is doubled and the weight on the inflation gap is halved to 1.3.